

UNIVERSITY OF PENNSYLVANIA

THE RELATION OF HETEROGENEOUS
AND HOMOGENEOUS CHROMATIC
STIMULI IN THE RANGE OF VISUAL
APPREHENSION EXPERIMENT

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A THESIS

in Psychology

presented to the faculty of the graduate school in partial
fulfillment of the requirements for the degree
of doctor of philosophy

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THE RELATION OF HETEROGENEOUS AND HOMOGENEOUS CHROMATIC STIMULI IN THE RANGE OF VISUAL APPREHENSION EXPERIMENT

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The present paper is a continuation of the series of studies in the 'range of visual apprehension' initiated by Fernberger's study¹ in 1921, where he, as Dallenbach² in 1920, came to the conclusion that the classical 'range of attention' experiment is not a problem in attention but rather one in apprehension. The conscious patterns which exist in this type of experiment were first analyzed and characterised by Oberly³ and further investigated by Cooper⁴ and Hart.⁵ The appropriateness of the terms used by Oberly and adopted in the succeeding papers to denote these patterns has been disputed, but the phenomena described have consistently been corroborated.⁶ The recent study of Glanville and Dallenbach,⁷ in addition to its verification of Oberly's analyses, contains a very complete historical account of the development of the 'range of attention' experiment and introduces a more neutral terminology than that previously employed. The terminology of the present paper conforms to that of Glanville and Dallenbach.

The previous studies from the University of Pennsylvania have already determined experimentally (1) the interrelation of the statistical limens of the three conscious patterns (Oberly), and

*Accepted for publication April 10, 1929.

¹S. W. Fernberger, A preliminary study of the range of visible apprehension, this JOURNAL, 32, 1921, 133.

²K. M. Dallenbach, Attributive *vs.* cognitive clearness, *J. Exper. Psychol.*, 3, 1920, 229.

³H. S. Oberly, The range for visual attention, cognition, and apprehension, this JOURNAL, 35, 1924, 332-352.

⁴S. F. Cooper, The effect of brightness in the range of attention experiment, *ibid.*, 40, 1928, 254-274.

⁵J. R. Hart, The range of visual attention, cognition, and apprehension for colored stimuli, *ibid.*, 40, 1928, 276-283.

⁶K. M. Dallenbach, Dr. Oberly on the 'range of visual attention, cognition, and apprehension', *ibid.*, 36, 1925, 154-156; Dr. Fernberger on the 'range of attention' experiment, *ibid.*, 38, 1927, 479-481; S. W. Fernberger, The 'range of attention' experiment, *idem.*, 478-479.

⁷A. D. Glanville and K. M. Dallenbach, Range of attention, *ibid.*, 41, 1929, 207-236.

the effect (2) of brightness (Cooper), and (3) of color (Hart) on these limens. The last was, however, concerned with only homogeneous chromatic stimuli. The present study considers both homogeneous and heterogeneous chromatic stimuli and their interrelations.

Summarily we may define, then, the problem of the present paper as an investigation of the effect of homogeneous and heterogeneous chromatic stimuli on the statistical limens of the three conscious patterns which Glanville and Dallenbach have called 'Unit,' 'Group,' and 'Mediate' Apprehension, and which correspond descriptively to those patterns designated, respectively, by Oberly as 'Attention,' 'Cognition,' and 'Apprehension.'

EXPERIMENTAL PROCEDURE

The stimulus-objects used in this experiment were colored circular dots of the four primary colors on a white background. The dots, 6.5 mm. in diam., were cut from the Hering papers—saturated yellow, blue, red, and green—and were pasted on white cards, 87 mm. sq. The stimulus-cards were grouped into 7 different stimulus-series—a 'series' being a set of 12 cards, on each of which there were a different number of dots. The smallest number of dots used was 3, and the greatest number was 14. These stimulus-series were, further, classified into two different groups, a 'homogeneous,' and a 'heterogeneous' group. The homogeneous group consisted of those series the cards of which bore stimulus-dots all of a single color; the heterogeneous group consisted of those series the cards of which bore stimulus-dots of two or more colors. The homogeneous group comprised (1) series Y, in which the stimulus-dots were all yellow; (2) series B, in which the stimulus-dots were all blue; (3) series R, in which they were all red; and (4) series G, in which they were all green. The heterogeneous group comprised (1) series Y-B, any card of which contained one or more blue and one or more yellow stimulus-dots; (2) series R-G, any card of which contained one or more red and one or more green stimulus-dots; and (3) series R-G-Y-B, any card of which contained one or more stimulus-dots of each of the four primary colors.

The manner of pasting the dots on the cards was, to begin with, haphazard. That is to say, the appropriate number was placed upon each of the 12 cards of one series at random. An accidental configuration resulted in the case of each number, which was reproduced in all the series. Thus there was a 3-dot pattern, a 4-dot pattern, and so on up to a 14-dot pattern; and these patterns were repeated in all the series of both the homogeneous and the heterogeneous groups. The form-quality of the stimuli was, in this way, kept constant.

In the heterogeneous group, a question arose in regard to the distribution, on the same card, of the two or more colors. The method adopted was as follows. The colors of each of the stimulus-series R-G, Y-B, and R-G-Y-B were repeated in succession an indefinite number of times forming three definite sequences: R-G-R-G-R-G etc. in the first series; Y-B-Y-B-Y-B etc. in the

second series; and R-G-Y-B-R-G-Y-B etc. in the last series. From each of these the first three colors were taken to construct the 3-dot card in the respective series; the next 4 colors were taken to construct the 4-dot card; and so on, until the 12 cards of each of the series were constructed. In the two-color series, series R-G and Y-B, the red and green and the yellow and blue were distributed equally on the cards containing an even number of dots, and unequally distributed on the cards containing an odd number of dots. In series R-G, the 3-, 7-, and 11-dot stimulus-cards contained one more red dot than green, and the 5-, 9-, and 13-dot cards, one more green dot than red. In series Y-B, the 3-, 7-, and 11-dot cards contained one more yellow dot than blue, and the 5-, 9-, and 13-dot cards, one more blue than yellow dot. In series Y-B, the yellow dots were given the position of the red dots, and the blue dots that of the green dots, of series R-G. This procedure was adopted so that there would be a greater evenness of color distribution in the series as a whole, the yellow and green pigment papers having a higher luminosity than the blue and red. In the four-color series, the colors were distributed equally only on the 12-dot stimulus-card, there being on this card 3 dots of red, three of green, three of yellow, and three of blue. As far as possible the different colors were distributed on the cards of this series so that the same color did not occupy contiguous positions.

The 7 series of 12 cards each were exposed in rotation by means of a Whipple tachistoscope,⁸ the exposure time being the same as Oberly's,⁹ 37.5 σ calibrated by the tuning-fork method. The order in which these 84 cards were exposed was haphazard, but no cards containing dots of the same color or color combination, or containing the same number of dots were exposed successively, except that 6-dot cards followed each other in one instance, and 7-dot cards followed each other in another instance. The position in which the cards were placed in the tachistoscope for the first exposure was recorded for each card. For the second exposure, the cards were rotated from this position 90°; for the third exposure, 180°; and for the fourth exposure, 270°. This manner of rotating the cards was followed throughout the experiment. For the fifth exposure, the cards were again in the first position. By following this method, the same card could appear in exactly the same position only after 336 exposures. In this way, and by terminating each period of observation at different places in the series so that a different card was exposed first at successive periods, the *O* was prevented from learning the order of exposure and from readily recognizing any particular card.

The experiments were conducted in a dark-room. The only light constantly present was that of the exposure lamps, thus keeping constant the illumination of the stimulus cards and the general illumination. *O* sat 1.9 m. from the exposure screen. He was instructed to look at the fixation-point on this screen at the signal word 'Ready.' A second later, the experimenter released the weighted arm of the tachistoscope, simultaneously giving the second signal word 'Now,' and the stimulus-card was exposed automatically. *O* then gave his report verbally, as quickly as possible, according to instructions which will

⁸G. M. Whipple, *Manual of Mental and Physical Tests*, I, 1924, 264 ff.

⁹Oberly, *op. cit.*, 334.

be described below, and *E* immediately recorded it. The *Os* were given practice in following these instructions before any judgment was recorded, and they were allowed to look at the instructions at the beginning of successive periods of observation whenever they so desired.

Observers. We used 5 *Os*—*A*, *G*, *M*, *N*, and *R*, all with scientific training. None of them had acted as *Os* in the earlier experiments mentioned above, but *A* and *G* were familiar with the type of work and the general experimental procedure. All the *Os* had, however, sufficient laboratory practice to put them at ease in the experimental situation of this problem and to enable them to accommodate quickly and adequately to the special procedures that we used.¹⁰

Instructions. The following instructions, essentially the same as those used by Oberly,¹¹ were given the *Os*.

"You will be shown successively, for a very short exposure, cards which contain a varying number of dots on a white background. Immediately after the exposure you will report verbally (1) the number of dots you have seen; (2) the degree of assurance of certainty of your judgment, using the following scale for your report: 5—if it is a 100 to 1 bet, 4—if it is a 5 to 1 bet, 3—if it is a 1 to 1 bet, 2—if it is a 1 to 5 bet, and 1—if it is a guess or if you do not know; (3) the method of determining your report—whether by 'immediate' judgment (*i.e.* ungrouped), by 'grouping,' or by 'counting.' 'Immediate' means that the dots are perceived in a single flash of attention and were ungrouped. 'Grouping' means that the dots are seen in a single flash of attention but were grouped. 'Counting' means that the report is made on the basis of some re-imaging of the stimulus-material, *i.e.* some mediating conscious process is used and the dots are counted in one way or another."

Two of the *Os* (*N* and *R*) returned 50 judgments for every one of the 84 stimulus-cards, and the other 3 (*A*, *G*, and *M*) returned 100 judgments for every card. The different series of cards were exposed on an average from 3 to 4 times in an observational hour. During the early stages of the experiment not so many exposures were made, but during the later stages more exposures were possible because the 3-dot cards were dropped when the *Os*, due to practice, invariably reported 4- and 5-dot cards correctly, and the 4-dot cards of the homogeneous series (except the yellow dot card) were dropped when the *Os* invariably reported 5- and 6-dot cards correctly. In the cases of 2 of the *Os* (*M* and *R*) all but three of the 5- and 6-dot cards (those of Series Y, Y-B, and R-G-Y-B) were dropped, late in the experiment, when the 7- and 8-dot cards were invariably reported correctly.

The average length of the observational periods was one hour, and the *Os* usually observed three periods a week. The *Os* were permitted frequent rests. In the cases of the *Os* who returned 100 judgments for every stimulus-card,

¹⁰I wish to express my appreciation of the splendid coöperation of my *Os*, and for their industry throughout the experimental period. My thanks are also due Professor Fernberger who suggested the problem and under whose direction it was carried out. His advice and criticism were both a help and an encouragement.

¹¹Oberly, *op. cit.*, 335. Cf. also S. F. Cooper, *op. cit.*, 257; Hart, *op. cit.*, 276.

an interval of at least a week lapsed between the first and second series of 50 judgments. The experimental work was begun in the winter of 1927 and completed in the summer of 1928.

RESULTS

In the following tables, the data based upon the judgments characterized as 'immediate' by the *Os* are classified under 'unit' apprehension; these data plus those based on the judgments characterized as 'grouped' are classified under 'group' apprehension; and these two types plus the data based on judgments characterized by the *Os* as 'counted' are classified under 'mediate' apprehension.¹² Judgments that were given with an assurance of less than '3,' or that did not give the correct number of dots exposed, were not considered in the statistical treatment of the results.

The observed relative frequencies. An examination of the percentages of correct judgments with an assurance of '5,' '4,' or '3' shows that the number of dots apprehended increases from 'unit' apprehension to 'group' and to 'mediate.'

A comparison of the results of the first and second series of 50 judgments—for those *Os* who returned 100 judgments for every stimulus-card—shows that the percentages correctly reported are greater for the second than for the first set. The increase is especially noticeable in 'group' and 'mediate' apprehension, particularly in the data of *G* and *M*. It is conspicuously apparent in the reports on stimulus-cards containing from 3 to 5 dots.

The limens. The statistical limens and measures of precision shown in Table I were obtained from the data by the method of constant stimuli. The limens of every stimulus-series increase, as a rule, from 'unit', to 'group', to 'mediate' apprehension.

The limens derived from the second series of 50 judgments show the effect of practice. They are greater in magnitude than those derived from the first, and the increase is largest for 'mediate' apprehension, less large for 'group' apprehension, and smallest for 'unit' apprehension.

¹²For an explanation and justification of this terminology see K. M. Dallenbach, Dr. Oberly on 'the range for visual attention, cognition and apprehension', this JOURNAL, 36, 1925, 155; and Glanville and Dallenbach, *op. cit.*, 220 f.

TABLE I

SHOWING THE LIMENS (L) AND THE MEASURES OF PRECISION (h) FOR EVERY ONE OF THE STIMULUS-SERIES FOR EVERY COGNITIVE STATE

O	Stimulus-series	'Unit' apprehension		'Group' apprehension		'Mediate' apprehension	
		L	h	L	h	L	h
A	Y	6.2	0.62	7.4	0.38	7.5	0.35
	B	6.2	1.02	7.3	0.33	7.4	0.31
	R	6.6	1.18	7.1	0.32	7.2	0.33
	G	6.3	1.11	7.6	0.27	7.7	0.29
	R-G	6.8	0.44	7.1	0.38	7.1	0.34
	Y-B	5.1	0.51	7.2	0.27	7.3	0.40
	R-G-Y-B	6.4	0.78	7.2	0.36	7.2	0.23
G	Y	5.8	0.37	6.1	0.32	6.7	0.24
	B	5.5	2.56	7.4	0.69	8.5	0.66
	R	5.1	2.11	7.3	0.74	8.6	0.61
	G	5.7	4.23	7.4	0.49	8.5	0.27
	R-G	5.3	1.44	7.0	0.54	8.5	0.48
	Y-B	4.2	0.69	5.0	0.38	5.4	0.33
	R-G-Y-B	5.1	0.43	5.4	0.40	5.8	0.32
M	Y	7.3	0.15	7.8	0.23	8.1	0.25
	B	8.8	0.37	8.1	0.47	9.7	0.26
	R	7.9	0.53	8.3	0.62	9.6	0.30
	G	8.2	0.50	7.9	0.64	9.8	0.26
	R-G	8.2	0.08	8.2	0.08	9.8	0.26
	Y-B	6.7	0.56	6.8	0.48	8.4	0.28
	R-G-Y-B	6.8	0.49	6.9	0.47	9.4	0.27
N	Y	5.3	0.47	6.1	0.35	7.0	0.28
	B	6.6	1.03	7.2	0.77	9.1	0.35
	R	6.8	1.71	7.3	1.04	9.0	0.29
	G	6.7	1.29	7.5	0.76	9.1	0.35
	R-G	6.5	0.66	6.3	0.47	8.4	0.32
	Y-B	6.2	1.02	6.2	0.58	7.1	0.31
	R-G-Y-B	6.2	0.66	6.6	0.59	7.9	0.37
R	Y	6.0	0.43	7.7	0.30	10.1	0.21
	B	7.2	0.46	8.6	0.33	10.4	0.11
	R	7.0	0.51	8.8	0.33	12.0	0.18
	G	6.8	0.46	9.0	0.30	11.8	0.20
	R-G	6.6	0.47	8.4	0.37	10.2	0.19
	Y-B	6.2	0.70	6.8	0.33	8.7	0.15
	R-G-Y-B	6.7	0.53	8.0	0.30	10.2	0.20

The rank orders of the different stimulus-series. Table II, derived from Table I, shows the rank orders of the limens of the different stimulus-series based upon the first set of 50 judgments. Rank 1, or first place, was given to the series whose limen was greatest in magnitude; rank 2, or second place, was given to the series with the next greatest limen; and so on to rank 7, or last place, which was given to the series whose limen was smallest in magnitude.

The data given in Table II were cast in the form of the scattergrams (Table III) which in turn were used as the basis of the final classification of the stimulus-series shown in Table IV.

The rank order given in Table IV was derived from Table III as follows: for every stimulus-series the sum of its rank orders 1-4 was compared with that of its rank orders 4-7. If the former was greater it was placed in the 'high' group; if the latter was greater it was placed in the 'low' group; and if the sums were approximately equal it was placed in the 'medium' group. It will be observed that the final order for the different stimulus-series is, with one exception, the same for every cognitive pattern. The exception occurs in 'unit' apprehension in which the stimulus-series occupying ranks 5 and 6 are the reverse of the ranks occupied in the other two cognitive patterns.

TABLE II

THE RANK ORDER OF THE STIMULUS-SERIES BASED ON THE MAGNITUDE OF THEIR RESPECTIVE LIMENS FOR EVERY O AND FOR EVERY COGNITIVE PATTERN

Cognitive pattern	Rank order	Observers				
		A	G	M	N	R
'Unit' apprehension	1	R-G	Y	B	R	B
	2	R	G	R-G	G	R
	3	R-G-Y-B	B	G	B	G
	4	G	R-G	R	R-G	R-G-Y-B
	5	B	R-G-Y-B	Y	R-G-Y-B	R-G
	6	Y	R	R-G-Y-B	Y-B	Y-B
	7	Y-B	Y-B	Y-B	Y	Y
'Group' apprehension	1	G	G	R	G	G
	2	Y	B	R-G	R	R
	3	B	R	B	B	B
	4	R-G	R-G	G	R-G-Y-B	R-G
	5	R-G-Y-B	Y	Y	R-G	R-G-Y-B
	6	R	R-G-Y-B	R-G-Y-B	Y-B	Y
	7	Y-B	Y-B	Y-B	Y	Y-B
'Mediate' apprehension	1	G	R	G	B	R
	2	Y	G	R-G	G	G
	3	B	B	B	R	B
	4	Y-B	R-G	R	R-G	R-G
	5	R-G-Y-B	Y	R-G-Y-B	R-G-Y-B	R-G-Y-B
	6	R	R-G-Y-B	Y-B	Y-B	Y
	7	R-G	Y-B	Y	Y	Y-B

The stimulus-series were similarly classified into 'high,' 'medium,' and 'low' upon the basis of the average limens of all the Os. These data appear in Table V. The rank orders given in Table IV may be called the 'preferential' orders, while those given in Table V may be called the 'statistical' order. The orders in both instances are, however, substantially the same; only five points of disagreement occur—two in 'unit' apprehension, one in 'group' apprehension, and two in 'mediate' apprehension—and they consist of the reversal of neighboring rank orders.

The classification of the stimulus-series into 'high,' 'medium,' and 'low' is, with one exception, the same in the two tables. The exception occurs in 'unit' apprehension in which the rank orders of series R and R-G are reversed. The numerical difference between these two series is, however, so small—0.024—that the discrepancy may be said not to affect the general tendency shown by

these tables. The highest limens—in order of preference—in all of the cognitive patterns for all of the *Os* collectively are stimulus-series G, B, and R; the medium limen is R-G; and the lowest limens are Y, R-G-Y-B, and Y-B.

TABLE III
SCATTERGRAMS OF THE RANK ORDER OF EVERY ONE OF THE SEVEN STIMULUS-SERIES FOR EVERY COGNITIVE PATTERN

Cognitive pattern	Rank order	Stimulus-Series						
		Y	B	R	G	R-G	Y-B	R-G-Y-B
'Unit' apprehension	1	1	2	1	0	1	0	0
	2	0	0	2	2	1	0	0
	3	0	2	0	2	0	0	1
	4	0	0	1	1	2	0	1
	5	1	1	0	0	1	0	2
	6	1	0	1	0	0	2	1
	7	2	0	0	0	0	3	0
'Group' apprehension	1	0	0	1	4	0	0	0
	2	1	1	2	0	1	0	0
	3	0	4	1	0	0	0	0
	4	0	0	0	1	3	0	1
	5	2	0	0	0	1	0	2
	6	1	0	1	0	0	1	2
	7	1	0	0	0	0	4	0
'Mediate' apprehension	1	0	1	2	2	0	0	0
	2	1	0	0	3	1	0	0
	3	0	4	1	0	0	0	0
	4	0	0	1	0	3	1	0
	5	1	0	0	0	0	0	4
	6	1	0	1	0	0	2	1
	7	2	0	0	0	1	2	0

The relation of heterogeneous to homogeneous stimuli. The distribution of the stimulus-series in Tables IV and V indicate the relative influence of homogeneous and heterogeneous stimuli on the *Os*' limens as a group. In every one of the cognitive patterns three of the four homogeneous stimulus-series make up the group of 'high' limens, and two of the three heterogeneous series fall within the group of the 'low' limens. Series Y, a homogeneous series, falls within the 'low' ranks, holding rank 6 in 'unit' apprehension, and rank 5 in 'group' and 'mediate' apprehension. Series R-G holds the fourth or 'medium' rank in all three of the cognitive patterns. From these data we may conclude that, under the conditions of our experiment, heterogeneity of stimuli gives, in most cases, a smaller limen than homogeneity. It is to be observed, however, that Y is a common factor in each member of the 'low' limen group, and, as we have seen, stimulus-series Y falls always within the 'low' order for all the cognitive patterns.

TABLE IV

RANK ORDER OF THE STIMULUS-SERIES FOR THE *Os* AS A WHOLE FOR EVERY COGNITIVE PATTERN, CLASSIFIED INTO GROUPS DESIGNATED 'HIGH,' 'MEDIUM,' AND 'LOW.' (FROM TABLE III)

Rank order	Cognitive patterns		
	'Unit' apprehension	'Group' apprehension	'Mediate' apprehension
High	1 G	G	G
	2 B	B	B
	3 R	R	R
Medium	4 R-G	R-G	R-G
Low	5 R-G-Y-B	Y	Y
	6 Y	R-G-Y-B	R-G-Y-B
	7 Y-B	Y-B	Y-B

TABLE V

RANK ORDER OF THE STIMULUS-SERIES FOR EVERY COGNITIVE PATTERN, BASED ON THE AVERAGE OF THE LIMENS OF ALL THE *Os* (From Table I)

Rank order	Cognitive patterns					
	'Unit' apprehension		'Group' apprehension		'Mediate' apprehension	
	Series	Av. L	Series	Av. L	Series	Av. L
High	1 B	6.9	G	7.9	G	9.7
	2 G	6.7	R	7.8	R	9.3
	3 R-G	6.7	B	7.7	B	9.0
Medium	4 R	6.9	R-G	7.4	R-G	8.8
	5 R-G-Y-B	6.3	Y	7.2	R-G-Y-B	8.1
Low	6 Y	6.1	R-G-Y-B	6.8	Y	7.9
	7 Y-B	5.9	Y-B	6.4	Y-B	7.4

It is also to be observed that the homogeneous and the heterogeneous stimulus-series holding the first four positions in the rank order for the *Os* as a whole are characterised by the absence of Y. From these facts, we may conclude that Y is an indispensable part of the cause of the low rank order of the heterogeneous stimuli. An experimental determination of this conclusion could be made by running additional two-color series, Y-R and Y-G, and three-color series, Y-R-G, Y-B-G, and Y-B-R.

The relation of the heterogeneous and homogeneous stimuli, in the case of every *O*, is shown quantitatively by Table VI. The statistical limens of each of the *Os* for the four homogeneous series and for the three heterogeneous series in each of the cognitive patterns were averaged, and the difference between these averages was taken. In every instance, the average heterogeneous limen is smaller than the homogeneous limen. If a dif-

ference of 0.5 or more is taken to be significant, there is a significant difference in 9 of the 15 cases (60%), and this difference increases from 'unit' to 'group,' to 'mediate' apprehension. For one *O*, *G*, there is a significant difference in each of the three cognitive patterns; for two *O*s, *R* and *N*, there is a significant difference in 'group' and 'mediate' apprehension; and for *M* there is a significant difference in 'unit' and 'group' apprehension. For *A* the difference is not significant in any of the cognitive patterns. We conclude from these data, therefore, that the range of visual apprehension for heterogeneous chromatic stimuli compared with that for homogeneous chromatic stimuli is significantly reduced.

This narrowing of the range of apprehension for heterogeneous stimuli is caused, in part, by heterogeneity, but the presence of *Y* is, we found, also part of the cause. Table VI, however, does not show to what extent *Y* is a causal factor, because *Y* appears in both the homogeneous and the heterogeneous groups and, therefore, affects both the homogeneous and the heterogeneous average limens. In order to show specifically the effect of *Y*, Table VII was constructed. The numbers, in Table VII, designated as 'high' are the averages of the three highest limens, those of stimulus-series *G*, *B*, and *R* (Table IV), and those designated as 'low,' the averages of the lowest limens, those of series *Y*, *R-G-Y-B*, and *Y-B*; series *R-G* was omitted from these calculations because

TABLE VI
THE AVERAGE LIMENS OF THE HOMOGENEOUS AND OF THE HETEROGENEOUS
STIMULUS-SERIES AND THEIR DIFFERENCES FOR EVERY *O* FOR
EVERY ONE OF THE COGNITIVE PATTERNS

<i>O</i>	'Unit' apprehension			'Group' apprehension			'Mediate' apprehension		
	Homo.	Hetero.	Dif.	Homo.	Hetero.	Dif.	Homo.	Hetero.	Dif.
<i>A</i>	6.3	6.1	0.2	7.4	7.2	0.2	7.4	7.2	0.2
<i>G</i>	5.5	4.9	0.6	7.1	5.8	1.3	8.1	6.2	1.9
<i>M</i>	8.0	7.3	0.7	8.0	7.3	0.7	9.4	9.2	0.2
<i>N</i>	6.4	6.3	0.1	7.2	6.3	0.7	8.5	7.8	0.7
<i>R</i>	6.8	6.5	0.3	8.5	7.7	0.8	11.0	9.7	1.3

TABLE VII
THE AVERAGE LIMENS OF THE 'HIGH' AND OF THE 'LOW' STIMULUS-SERIES
AND THEIR DIFFERENCES FOR EVERY *O* FOR EVERY ONE OF
THE COGNITIVE PATTERNS

<i>O</i>	'Unit' apprehension			'Group' apprehension			'Mediate' apprehension		
	High	Low	Dif.	High	Low	Dif.	High	Low	Dif.
<i>A</i>	6.3	5.9	0.4	7.4	7.3	0.1	7.4	7.3	0.1
<i>G</i>	5.4	5.1	0.3	7.4	5.5	1.9	8.5	5.9	2.6
<i>M</i>	8.3	6.9	1.4	8.1	7.1	1.0	9.9	8.6	1.3
<i>N</i>	6.7	5.9	0.8	7.3	6.3	1.0	9.0	7.3	1.7
<i>R</i>	7.0	6.3	0.7	8.8	7.5	0.3	11.4	9.6	1.8

it gave the medium limen throughout. By this method Y was eliminated entirely from the set of averages designated as 'high,' and was a factor in every one of the series whose limens were averaged for the set designated as 'low.' In this way, then, the influence of Y on the thresholds may be more specifically shown.

The difference, for the majority of Os, between the 'high' and the 'low' average limens (Table VII) is greater than that between the homogeneous and heterogeneous average limens (Table VI)—the difference in the former case being less than 0.5 only four times, while in the latter case it is less six times, out of fifteen. In other words, the effect of Y is significant in 73.6% of the instances, while the effect of heterogeneity was, we saw, significant in only 60% of the instances. At least one significant difference is to be noted in Table VII for every O: *M* and *N* show significant differences in all three of the cognitive patterns; *R* and *G* in two of the patterns; and *A* in one. It is obvious from these data, then, that for our group of Os, as a whole and under our experimental conditions, Y reduces the range of visual apprehension for chromatic stimuli more, and to a greater extent, than does heterogeneity of stimuli.

Table VIII gives quantitative corroboration to the general conclusions that followed from the data given in Tables IV and V, namely, that the R-G limens differ least from the three high homogeneous limens, the Y-B limens differ most from the homogeneous limens and the other heterogeneous limens, and the Y limens differ very little from the low heterogeneous limens. If we consider the average differences, tabulated in the last column of Table VIII, for each cognitive pattern, we observe, in the first place, that the average limens for R-G do not differ significantly from the average of all the homogeneous limens, the R-G average limen being only 0.105 larger in 'unit' apprehension, 0.199 smaller in 'group' apprehension, and 0.070 smaller in 'mediate' apprehension, than the average homogeneous limen. In the second place, the average limen for Y-B is significantly smaller in each cognitive pattern than the average limens of the homogeneous series as a whole, the Y-B limen being 0.900 smaller in 'unit,' 1.212 smaller in 'group,' and 1.499 smaller in 'mediate' apprehension than the average homogeneous limen. The average limen for R-G-Y-B is also significantly smaller than the average limens for the homogeneous stimulus-series as a whole in 'group' and 'mediate' apprehension, but not in 'unit.' In the third place, the average limen for stimulus-series Y is not significantly different from the average limens for the heterogeneous stimulus-series in any of the cognitive patterns: the limen for Y being but 0.092 larger in 'unit' apprehension, 0.128 smaller in 'group' apprehension, and 0.069 larger in 'mediate' apprehension.

The averages tabulated in the bottom row of Table VIII show the amount and the direction of the differences of the averages for the heterogeneous and the homogeneous limens for all the Os. The average heterogeneous limens differ significantly in every cognitive pattern from the average homogeneous limens with the exception of the case of stimulus-series Y. In 'unit' apprehension the average heterogeneous limen differs most from the average limen for stimulus-series B; in 'group' and 'mediate' apprehension it differs most from

the average limens for series G. In general, the average differences when minus, *i.e.* when the heterogeneous limens are smaller than the homogeneous, increase from 'unit,' to 'group,' to 'mediate' apprehension.

TABLE VIII

THE AVERAGE OF THE DIFFERENCES OF EACH OF THE HETEROGENEOUS LIMENS AND EACH OF THE HOMOGENEOUS LIMENS FOR EACH COGNITIVE PATTERN FOR THE OS AS A WHOLE

(The plus and minus signs indicate that the average heterogeneous limen is larger or smaller, respectively, than the average homogeneous limen compared with it)

Cognitive pattern	Heterogeneous	Homogeneous				Av.
		Y	B	R	G	
'Unit' apprehension	R-G	+0.585	-0.168	+0.024	-0.023	+0.105
	Y-B	-0.437	-1.191	-0.998	-0.975	-0.900
	R-G-Y-B	+0.129	-0.623	-0.430	-0.407	-0.283
	Av.	+0.092	-0.661	-0.468	-0.468	
'Group' apprehension	R-G	+0.412	-0.364	-0.337	-0.506	-0.199
	Y-B	-0.596	-1.353	-1.365	-1.534	-1.212
	R-G-Y-B	-0.200	-0.937	-0.949	-1.118	-0.776
	Av.	-0.128	-0.885	-0.884	-1.053	
'Mediate' apprehension	R-G	+0.930	-0.016	-0.485	-0.711	-0.070
	Y-B	-0.478	-1.644	-1.893	-1.982	-1.499
	R-G-Y-B	-0.246	-0.900	-1.169	-1.259	-0.894
	Av.	+0.069	-0.853	-1.182	-1.317	

The conscious patterns. The Os were required by the instructions in this experiment to designate the method of determining their reports as 'immediate,' 'grouped,' or 'counted,' according to certain general characterizations given them. This was not as simple as we had been led by previous experiments to believe. All the Os experienced difficulty at times in deciding the method which served as the basis of their reports.

The first category, 'immediate,' appeared to be unequivocal. Whenever the number of dots was apprehended immediately in a single flash of consciousness the judgment was given promptly and without hesitation. A few times, however, G and N reported some difficulty in deciding whether the judgment was 'grouped' or 'immediate.'

The second category, 'grouped,' appeared to be equivocal. This term was, by definition, used to designate the conscious pattern

when the stimulus was perceived immediately, the number of dots appearing with different degrees of clearness, that is, attentional grouping of the dots occurred. This method of determining the report occurred rarely and it was thought by most of the *O*s to be due to some factor in the stimulus, *e.g.* to the different colors, to the particular arrangement of the dots on the stimulus-cards, or to both.

M reported that the conscious pattern 'grouped' was rarely experienced. Of the recorded judgments of this *O*, only 16 of the 4200 judgments of the first set were characterized as 'grouped,' all of these being early in the experimental work; none of the second set of judgments was so characterized.

G reported that he "was sometimes in doubt whether the judgment was 'immediate' or 'grouped,'" and found it "difficult to know if the grouping was objectively given or did I do it myself." Most of the judgments of the 6-dot stimulus-cards were given as 'grouped' by *G* but he felt that this grouping was certainly due to the objective arrangement of the dots.

N, who gave a fair percentage of 'grouped' judgments, stated that "grouping by colors was the rule." He commented that "anything above a 5, that is, the 6s and 7s, usually were grouped."

A reported that "grouping depends on the position of dots on the cards." A judgment was called 'grouped' when the dots were "arranged in a number of separate groups." *A* gave the highest percentage of 'grouped' judgments; the psychometric functions of 'group' and 'mediate' apprehension, graphically presented, appear in his case almost to coincide.

The third category, 'counted,' appeared to be not as unequivocal as the first but less equivocal than the second. A report made on the basis of some subsequent, mediating, mental processes, involving some kind of re-imaging of the stimulus material, was called 'counted.' Most of the *O*s characterized the greater part of the judgments recorded in the third category, "grouped plus counting." They reported that the dots were divided into groups, wholly or in part, and the final sum was found by adding together the sum of the individual groups or, by adding together the sum of the groups and the remaining single scattered dots.

The introspections raise a question as to the causes, under the conditions of this experiment, of the variability of the categories in their application. Our experimental data do not, however, give us the material for an answer. Further experimental work is needed to determine what, under the conditions of our experiment, are the causes affecting the stability of these categories.

The effect of color on the range of visual apprehension. Hart investigated the effect of chromatic homogeneous stimuli on the range of visual apprehen-

sion and found that red gave the largest limen, green the smallest, and yellow and blue limens of intermediate size.¹³ We found in this experiment that in general green gave the largest limen, yellow the smallest, and blue and red limens intermediate in size. In other words, the order of single colors based on the serially decreasing magnitude of the respective limens was found by Hart to be (1) red, (2) yellow, (3) blue, (4) green; while the order on the basis of our data was found to be (1) green, (2) blue, (3) red, (4) yellow. How may these differences be accounted for? The same set of chromatic papers were used in each experiment, and the stimulus-objects were dots. Hart, however, presented the dots on a gray background, while in the present study the dots were presented on a white background, the other conditions of the two experiments being the same—the pre-exposure field being black and the tachistoscope being operated in a dark-room. The difference in the background of the stimulus dots may or may not be the chief cause of the differences in the magnitude of the limens of the respective colors in the two instances, but, in either case, it must be considered part of the cause of the recorded differences.

According to the introspective notes, the *Os* in our experiment experienced difficulty in making judgments at certain times, if not all the time, on account of the characteristics of a single color or of the grouping of different colors, although each *O* remarked, at some time during the experiment, "color doesn't seem to make much difference."

In the case of single colors, yellow occasioned the greatest difficulty. This was due, it was reported by every *O* at some time, to the "faintness of the yellow," which made it "difficult to see the yellow." At the beginning of the experiment, when a card of stimulus-series Y was exposed, the *Os* reported "only a flash of yellow," or "nothing at all," or "just a bunch of yellow."

M reported at first exposure of the 8-dot card of series Y, "can't see anything at all;" and at the 37th exposure of the cards, "yellow always hard to get."

R remarked on the 7th exposure of the 4-dot card of series Y, "white hardest to see," on the 14th exposure of the 8-dot card, series Y, "can't see at all," and on the 17th exposure, 13-dot card, series Y, "can't see all the yellow dots."

N stated, "I do most of my counting from a kind of after-image and yellow doesn't leave much of a memory image." At the 1st, 17th, 20th, and 42d exposures of some of the cards of series Y, he reported, "yellow, but I can't see the number, too faint."

For *G*, from the 1st to the 50th exposure, in both the first and second sets of judgments, the yellow dots were always a cause for some exclamation of disgust or displeasure, especially when more than 6 dots were exposed.

In the case of mixed colors, fewer difficulties were experienced but more were occasioned by Y than by the other single colors, R, G, and B. When cards of 8 dots and upwards of the four-color series R-G-Y-B were exposed several of the *Os* spoke of the "awful mixtures." The majority of the *Os* re-

¹³J. R. Hart, *op. cit.*, 283.

ported that the Y-B combination was the hardest, but it was the Y-factor that was mentioned as the most bothersome, here again, due to its faintness.

Thus, we may say that Y appears to have had, introspectively, more effect on the judgments of the number of stimulus dots apprehended than any other single color and any color combination.¹⁴

The dot-patterns and their configuration. A phenomenon occurred during the progress of the experiment which we shall call, for want of a better name, 'configuration of the dot-patterns.' By this term, we mean, the tendency on the part of the Os to perceive a certain number of stimulus dots as in a particular form or configuration and, then, consciously or unconsciously, to take hold of the particular configuration perceived as the 'sign' of the number of dots exposed.

For example, A reports, "after several trials a number of the arrangements of dots was nearly always the same and I could be sure of five even though I had not been able to perceive all the dots, just because of the arrangement, for six never appeared in certain of the arrangements which five always appeared in. With the larger number of dots, when a certain arrangement appeared time after time, I learned to give attention more definitely to a certain part of the dots, and as a consequence could even increase the number of dots which I could perceive."

G reported, "as the experiment goes on apperception plays an increasingly greater rôle, sometimes consciously, sometimes unconsciously. I've observed that I have been giving degrees of assurance in the latter part of the experiment that I couldn't have given before, take 7 for example, no matter how turned around, I always get it in groups of 3 and 4. I got to know the pattern; and if I didn't see all of the dots, due to lax attention, I'd fill it in. The manner of judging goes toward the 'immediate'-end by getting less 'grouped' and 'counted' and more just 'grouped.' Now I know how the patterns of 6 and 7 look. . . . and 10 equals three lines and a curly cue. I don't have to give my full attention, just a glimpse is sufficient."

At the beginning of the experimental work, however, the cards of the various series containing the same number of dots on different exposures appeared, to all the Os, to be different. G, for example, remarked that "even when there are the same number of dots, the pattern seems different and therefore it is sometimes easier and sometimes harder to judge the number;" and suggested that "the same number of dots in each series might have been arranged in the same pattern." It was not until later in the experiment that the Os perceived certain numbers as particular configurations.

¹⁴The term configuration as used in this paper does not imply any opinion, on the part of the writer, as to the positions taken by the *Gestalt* School whose fundamental concept, *Gestalt* or *Struktur*, has, in English, been rendered by the term 'configuration.'

Spontaneous comments on the special configurations of certain numbers of dots were made earlier or later in the experimental work and at different times by the different *Os*. *M*, on the 8th exposure of the stimulus cards observed that a 7-dot card was "upside down," and on the 22d exposure greeted a 7-dot series B card as an "old friend," apprehending the number of dots 'immediately' (previously the number had been reported 'counted'). *N* on the 28th exposure stated that the 7- and 6-dot cards were "remembered." *R* on the 41st exposure remarked, after a 7-dot card had been exposed, "a bunch of sevens of this form." *G* was not sure of the 7-dot pattern in any of the series until the second set of 4200 judgments, that is, after, at least, 50 exposures. *A* made no specific comment on the 7-dot pattern in either the first or second set of judgments.

Such variability from *O* to *O* in the time of the beginning of configuration of the dots of the different stimulus-cards, as we have indicated in the case of 7 dots, was shown in the case of all the numbers of stimulus dots (that were configured) above 5 or 6, and varied from series to series for any one *O*. Further, configuration seemed to reach an upper limit at different numbers of dots for different series, varying among the *Os*, the limit probably bearing a direct relation to the respective limens for 'unit' apprehension.

The factors upon which this configuration depends are not specifically given among the experimental data of the present investigation. Certain indications are, however, apparent. It may be held that configuration depends, in this experiment, upon the stimuli, since the dot-patterns were the same for all the series. But the manner of rotating the stimulus cards for each successive exposure, so that not before 336 exposures were made could the same card appear again, and the fact that cards with the same dot-pattern were not, at any time, exposed consecutively prevented the *Os* from easily learning the order of the exposure and readily recognizing the dot-patterns.

It is, no doubt, true that configuration, in our experiment, depends, in part, upon certain objective factors, for example, the arrangement of the dots upon the stimulus cards and the color or color-mixture of the dots. But it is also true that configuration depends, in part, upon certain subjective or psychosomatic factors, for our experimental data show that configuration began at different times in the progress of the experiment in the case of different *Os*, and that the extent and degree to which this phenomenon affected the judgments varied from *O* to *O*. It appears, therefore, that configuration depends, in part, upon the peculiar mental abilities and 'set,' of the individual *Os*. Thus, we may say that configuration is both a function of the stimulus and of the experiencing individual.

CONCLUSIONS

(1) The statistical limens for each of the three cognitive patterns for all the stimulus-series hold, in general, the following relations: the value of the limens for 'unit' apprehension are smallest in magnitude; those for 'mediate' apprehension, largest; and, for the most part, those for 'group' apprehension are intermediate.

(2) The interrelation of the statistical limens of the different series for each of the three cognitive patterns is, in general, as follows: the limens greatest in magnitude are given, on the average, by series G, B, and R; the limens intermediate in magnitude, by series R-G; and the limens smallest in magnitude, by series Y, R-G-Y-B, and Y-B.

(3) The color preference of the group of Os as a whole, indicated by the serially decreasing magnitude of the respective limens, is as follows: (1) G, (2) B, (3) R, (4) R-G, (5) Y, (6), R-G-Y-B, (7) Y-B. The order of the homogeneous series according to the decreasing magnitude of respective limens is (1) G, (2) B, (3) R, and (4) Y; and of the heterogeneous series, (1) R-G, (2) R-G-Y-B, and (3) Y-B.

(4) Heterogeneity of chromatic stimuli tends, under the conditions of this experiment, to reduce the magnitude of the limens for each of the three cognitive patterns, least for 'unit' and most for 'mediate' apprehension.

(5) The results of the present study indicate that yellow is an indisputable factor in the cause of this reduction of the range of visual apprehension by heterogeneity of chromatic stimuli, but what the exact rôle of yellow is cannot be determined under the conditions of the experiment and would require a special investigation.

(6) A comparison of the introspective notes of our Os indicated a certain degree of instability in the functioning of the three categories under the conditions of our experiment. The category 'immediate' appeared to be least equivocal, that of 'counted,' medially so, and that of 'grouped,' most equivocal.

(7) As the experiment progressed, and perhaps as the effect of practice, the stimulus-dots became configurated. The Os

recognized the dots as having a definite form or pattern. This configuration affected the *Os*' judgments in two respects: (1) conscious momentary "wanderings of the attention" did not interfere with the apprehension of the correct number of dots; the recognition of their structure, sometimes accomplished in the periphery of consciousness, acted as a 'sign' of the number of dots; (2) the conscious pattern 'counted' disappeared in most cases after the configuration of certain stimulus-cards was established, and in these cases the conscious patterns 'immediate' or 'grouped' appeared instead.

The amount of practice required before this configuration began varied from *O* to *O*, and in the case of every *O* the number of dots which formed such a figure, within the limits set by this experiment, was relative to the statistical limen for the stimulus-series in question.

The specific factors upon which this configuration depends cannot be determined without further experimentation, but it appears to be both a function of the stimulus and of the experiencing individual.

